Chemical properties of an Ultisol under *Leucaena leucocephala* (Lam) de Wit and *Cajanus cajan* (L.) millsp. alley cropping systems in southern Bénin after six years of continuous cultivation

T. P. AKONDE[1]

Abstract

An alley cropping experiment was carried out during 6 years Bénin on a field previously used as about 4 years bush-fallow. A no-tree control was compared with *Leucaena leucocephala* (Lam) de Wit and *Cajanus cajan* (L) Millsp grown in 4 m distant hedgerows. In the same experiment, application of 90-30-75 kg ha^{-1} NPK fertilizer vs. no fertilizer and maize-cassava intercropping vs. rotation of sole crops was also tested. Topsoil samples (0-30 cm) were taken initially and after 6 years. After 6 years of continuous cropping, *Leucaena leucocephala* led to a higher total N, organic C, P $Bray^{-1}$, exchangeable Ca and CEC, but to a lower exchangeable Mg, K and Na than the control. *Cajanus cajan* slightly increased exchangeable Ca and CEC. In the non fertilized treatments, there were no significant differences between soil pH in plots without hedgerows and those with hedgerows. No significant differences in soil properties were recorded between maize and cassava solecropped in rotation, and maize and cassava intercropped. However, values of all elements were higher in rotated plots, except Ca, K and Na.

Key words: Alley cropping, exchangeable cations, organic C, soil fertility, total nitrogen, *Cajanus cajan, Leucaena leucocephala*, Bénin.

Propriétés chimiques d'un Ultisol au Sud Bénin dans des systèmes de cultures en couloirs à base de *Leucaena leucocephala* (Lam) de Wit et *Cajanus cajan* (L.) millsp. après six ans de culture continue

Résumé

Un essai de cultures en couloirs a été mené pendant 6 ans au Sud Bénin sur un champ qui était précédemment avec une jachère de 4 ans environ. Un traitement contrôle a été comparé avec des haies de Leucaena leucocephala (Lam) de Wit et Cajanus cajan (L) Millsp placées à 4 mètres les unes des autres. Dans le même essai, une application d'engrais minéraux NPK de 90-30-75 kg/ha a été comparé à un traitement sans application d'engrais et une association de maïs-manioc à un traitement consistant en une rotation maïs et manioc en cultures pures. Des échantillons de sol (0-30 cm) ont été prélevés au début et ensuite après 6 ans d'expérimentation. Après 6 ans de cultures continues, les haies de Leucaena leucocephala ont conduit à des valeurs plus élevées de N total, de C organique, de P $Bray^{-1}$, de Ca et de CEC échangeables, mais à des valeurs plus basses de Mg, K et Na échangeables. *Cajanus cajan* a augmenté légèrement la CEC et le Ca échangeables. Dans les traitements sans fertilisation, il n'y a pas eu de différences significatives en ce qui concerne les valeurs de pH au niveau des parcelles sans haies et celles avec des haies. On ne note pas non plus de différences significatives en ce qui concerne les valeurs des propriétés de sol entre le maïs et le manioc en rotation et l'association entre le maïs et le manioc. Cependant, en dehors du Ca, K et Na, les valeurs de tous les autres éléments sont plus élevées au niveau des parcelles en rotation.

Mots clés : Cultures en couloirs, cations échangeables, C organique, fertilité de sol, N total, *Cajanus cajan, Leucaena leucocephala*, Bénin.

[1] Institut National des Recherches Agricoles du Bénin, 01 BP 884 Recette Principale Cotonou (République du Bénin), Tél (+229) 30 02 64, Fax (+229) 30 07 36

Introduction

Many works were published on the effects of prunings from tree hedgerows on chemical and physical properties of soils (HULUGALLE and KANG, 1990; ROSECRANCE et *al.*, 1992). Most of the researches in Africa have been conducted in the humid tropical zone of Nigeria on Entisols and Alfisols. Very few alley cropping trials were carried out on not degraded “terre de barre” or Ultisols in the subhumid savanna zones of west Africa.

The “terre de barre” soils occur from southern Togo to southern Nigeria (RAUNET, 1973). Their inherent soil fertility is low (LOUETTE, 1988). To maintain their fertility for continuous and intensive cropping, fertilizers or manures have to be applied (JANSEN, 1993). Most of the small scale farmers, however, do not have access to fertilizers, either because of high costs or infrastructural problems (KANG, 1986). To restore soil fertility, farmers traditionally fallow their land for a relatively long period before cropping it again. But in many regions, high and increasing population densities have compelled the farmers to reduce fallow periods (OKIGBO, 1974; FLOQUET, 1991a; FLOQUET, 1991b). With short fallow periods, the degree of soil fertility restoration of slash and burn systems is usually low. The overall consequence is that the fertility of soils decreases leading to low yields (VAN REUTLER and PRINS, 1993). Therefore, the question of how to handle the soil in way such that its fertility is maintained or even improved is a major goal of improved cropping systems.

Looking for a way to counteract the decline of soil fertility in West Africa, agroforestry systems were proposed and alley cropping is one of these systems (KANG et *al.*, 1990).

Some studies on alley cropping have shown that an improvement of soil fertility was the result of combination of faster and more efficient recycling of nutrients, improved soil structure and water availability (LAL, 1989a; LAL, 1989b; KANG and WILSON, 1987; KANG et *al.*, 1990). However, very little information is available about the interaction between alley cropping systems, and fertilizer application on Ultisols.

This study was aimed at examining the impact of continuous application of prunings in *Leucaena leucocephala* and *Cajanus cajan* alley cropping systems on the chemical properties of an Ultisol in the subhumid savanna zone of west Africa.

Material and methods

A field trial was carried out on the International Institute of Tropical Agriculture (IITA) at Abomey-Calavi in southern Benin (6°24’ N, 2°20’ E) between 1986 and 1992. The climate is subhumid-tropical with an annual rainfall of 1,165 mm in the 25 years average (1967-1992) and an annual mean temperature of 27.2 °C. The rainfall pattern is bimodal with a long rainy season of 4 months from April to July followed by a short dry season of 6 weeks and then by short rainy season of 2 months from September to October. During the trial period, rainfall dropped below average (less than 1,000 mm) in 3 years (1986, 1989, and 1990) and was more than the average in the other years (table 1). Abnormal rainfall distribution occurred only in 1987 when the beginning of the first raining season was delayed from April to May and in 1990 when the short raining season was extended until December. The soil was classified as a clayey, kaolinitic, isohyperthermic Paleustult (Ultisol) of low fertility. The experiment was designed as a combined split-block, split- plot with three replications. Three alley cropping treatments (no-alley control, *Leucaena* and C*ajanus* alleys) and two fertilizer treatments (with vs. without NPK at 90, 39 and 75 kg $ha^{-1}.year^{-1}$, respectively) formed main - plots arranged in a split-block design. Two cropping systems were randomised as subplot: Solecropping of maize and cassava in crop rotation vs. intercropping of maize and cassava. Subplot was 12.0 m long and 10.6 m wide and contained 15 plant rows at 0.8 m distance. In alley cropping treatments a tree hedgerow replaced every 5th crop row so that hedges were 4 m apart. Within-row spacing for cassava was 0.8 m (15, 625 plants ha^{-1}), for maize 0.4 m (31,250 plants ha^{-1}), and for trees 0.5 m (5,000 plants ha^{-1}).

The history of the site is unknown. A fallow of 2-3 m tall bushes was hand cleared in April 1986 and then tilled 30 cm deep by disc plough. *Imperata cylindrica* rhizomes were removed by hand. Land preparation in subsequent years was done with large hand hoes. All plants were established at the end of April or early in May. *Leucaena* (K 28) was sown only once in 1986 at the depth of 5 cm after seed scarification in boiling water for 3 minutes. *Cajanus* (perennial, local variety) was sown 8 cm deep and resown every year from 1989 onwards. The maize variety TZRW with a growing cycle of 4 months was sown with 2 seeds per stand and thinned after emergence to one plant per stand. Cassava variety TMS 30572 was planted using 20 cm stakes after soaking them in a pesticide solution of 4 g Manzate D (Dithiocarbonate) + 1 g Malathion (4 % WP) per litre to prevent damage from soil born diseases and pests. Mineral NPK fertiliser was applied at the time of the first weed hoeing of maize in mid May each year.

Before and after 6 years of continuous cropping, soil samples (0-30 cm) were taken from each sub-subplot, air-dried, sieved and analysed for chemical properties at the Centre National d'Agropédologie in Agonkanmey, near Cotonou (Benin Republic), using methods described by JUO (1979) and BOKO and VINH (1979).

Table 1: Monthly rainfall distribution 1986-92 [mm] at the IITA-Station Cotonou, Benin Republic

Month	Rainfall (mm) in year					
	1986	1987	1988	1989	1990	1991
January	0.0	0.0	6.0	0.0	0.0	14.5
February	51.2	13.7	34.0	0.0	11.8	27.0
March	91.0	96.6	43.0	64.2	7.4	106.9
April	163.0	17.3	160.8	176.6	166.8	226.5
May	89.0	85.8	145.4	98.1	88.9	157.4
June	288.1	259.6	330.5	149.1	148.3	182.8
July	25.2	46.4	96.9	96.7	158.3	356.9
August	0.0	301.2	39.1	116.5	0.0	53.8
September	75.6	364.5	183.6	92.6	87.9	106.4
October	157.3	198.0	159.3	189.8	122.6	139.0
November	27.8	3.4	21.8	1.3	20.8	2.4
December	0.0	0.0	45.4	0.0	146.0	33.0
Total	968.2	1386.5	1265.8	984.9	948.8	1406.6

Results and discussion

Effect of alley cropping and interactions between alley and cropping systems

Table 2 shows that six years of continuous cropping resulted in a decrease in soil organic C, total N, pH (H_2O), exchangeable K, Mg and Ca with and without hedgerow integration. Decreases of organic C, total N and exchangeable Ca were lowest in alley cropping with *L. leucocephala* and CEC was considerably reduced in all treatments as compared to 1986, but it was far less in both alley cropping treatments. Compared to the beginning of the experiment pH decreased from 6.4 to 5.5 and 5.3 respectively in *L. leucocephala* and *C. cajan* treatments. The decline in values of exchangeable Ca, Mg and K which ranged from 42 to 48 per cent for Ca, 59 to 62 per cent for Mg and from 77 to 81 per cent for K may be attributed to nutrient export by harvest and nutrient losses through leaching.

After the trial period, soils under *Leucaena* had the significantly highest contents of organic C, total N. Available Bray I-P values were influenced by the fertilization treatments and will be more explained in the following passage. Both alley cropping systems had about the same content of exchangeable Ca, which reached 1.5 and was 12 per cent higher than the control without hedgerows. K content with *Leucaena* was the same as that of the control treatment, the lowest being under *Cajanus*. There were no significant differences in soil pH (H_2O) among treatments.

The slightly high organic C, total N, exchangeable Ca and available Bray I-P contents in alley cropping systems after 6 years were probably due to the contribution from the leguminous prunings. Similar results were recorded by LAL (1989b) on an Alfisol at Ibadan (Nigeria). This author found that soil organic matter content, total N, pH, and exchangeable bases, decreased in all alley cropping treatments after six years of continuous cropping. The same author reported that the magnitude of changes in these properties, however, was different among treatments and that the soil nutrient depletion was less severe in systems with *L. leucocephala*. MATTHEWS et *al.* (1992), in the northern province of Zambia also found no improvement in soil chemical properties over a 4 years' period on Orthic Ferralsol, and concluded that there was no evidence that alley cropping facilitated or enhanced nutrient recycling. GICHURU and KANG (1989) reported that *Calliandra* prunings did not influence significantly soil chemical characteristics on an Oxic Paleustalf at Ibadan (Nigeria) but for the same location, KANG et *al.* (1985) and YAMOAH et *al.* (1986) found an improvement in soil chemical properties in alley cropping over the control. Our results indicate that alley cropping may enhance nutrient status compared to control, but at a lower level than at land clearing even if the preceding bush fallow period was rather short.

The combination of alley cropping and cropping systems resulted in significant interactions related to pH (H_2O) only (Data not shown). This means that both systems may induce soil depletion. Within *Leucaena* hedgerows, both solecrop/rotation and intercrop showed the same level of total N amounted to 0.051 and 0.052 per cent, respectively. Within solecrop, organic C amounted to 0.65 and 0.62 with *Leucaena* and *Cajanus* treatments, respectively, although within intercrop its value was 0.72 in case of *Leucaena* treatment and 0.57 and 0.53 in case of the control and *Cajanus* treatments, respectively. Higher values of organic C and total N observed within *Leucaena* hedgerows regardless of cropping systems as compared to *Cajanus* or control treatment may be due to higher organic matter inputs through prunings and small branches. Pruning contribution from *Leucaena* amounted to about 5t ha^{-1} whereas in case of *Cajanus*, it was only about 3t ha^{-1}.

High exchangeable Ca and pH values were recorded on *Leucaena* alley plots, with rotation of maize and cassava. This could be attributed to the relatively high release of Ca from the *Leucaena* prunings which is about 55 kg ha^{-1} $year^{-1}$ and the relatively low Ca removed from the field through maize grain or cassava root yields which amounted to 0.6 and 5.5 kg ha^{-1} $year^{-1}$**,** respectively, as indicated in previous report (AKONDÉ et *al.,* 1997).

Fertilization effect

Even N, P and K fertilization could not maintain initial level of soil chemical properties, except available P which increased fourfold in the fertilized plots. All other values decreased over time. Fertilizer application reduced organic C, total N, exchangeable Ca and Mg, and the sum of bases, but not at a significant level as compared to unfertilised plots. By contrast, K and Na levels increased significantly ($P \leq 0.10$) in fertilized plots as compared to unfertilised plots. Similar results were recorded by AGBENIN and GOLADI (1998) on a savanna Alfisol in the northern guinean zone of Nigeria. They found that fertilization with NPK, reduced CEC, exchange cations and upset the cationic balance and that significant decreases in C, N and organic phosphorus concentrations occurred in aggregates of the cultivated soils compared with the native site.

Base saturation was lower in fertilized plots due mainly to losses of exchangeable Ca and Mg. Decreases in exchangeable Ca due to six years of intensive cropping amounted to 41 per cent for non-fertilization treatments. In the case of Mg, the corresponding decreasing levels reached 54 and 69 per cent, respectively. Reduction in base saturation falls in line lower values of pH in fertilized plots, the latter being attributed to acidification resulting from NPK fertilizers (FINK, 1979).

After six years of cropping, lower values of pH, organic C and total N were recorded in both fertilized and unfertilized plots suggesting nutrient losses by leaching and exports by harvest products. CEC decrease may be attributed to the decomposition of organic C. Values of pH declined from 6.4 to 5.2 and 5.6 in fertilized and non-fertilized plots, respectively. Soils in southern Bénin are coarsely textured and poorly buffered (RAUNET, 1973) favoring soils acidification with fertilizer application (LOUETTE, 1988). JONES (1976) and JONES and STOCKINGER (1976) reported soil acidification to be accompanied by losses of exchangeable Ca and Mg. Obi (1989) found that continuous cropping of a tropical Ultisol with or without nitrogen fertilizer increased soil acidification, reduced soil organic matter, and thus led to low crop yields. DIATTA and SIBAND (1998) found that in Casamance (Sénégal), on degraded soils, mineral fertilizer associated with organic matter had led to a significative increase. One of the best methods to minimise fertilizer induced soil acidification might be through liming or use of alkaline fertilizers.

Table 2: Soil chemical properties (0-30 cm) of an Ultisol after six years of continuous cropping as affected by alleycropping (AL), fertilization (F) and cropping systems(CR) in southern Benin

Year	Treatment		pH (H_2O)	Total N (%)	Org. C (%)	P(Brayl)* $mgkg^{-1}$	Exchang. Base ($C.mol*kg^{-1}$. soil)				CEC $C.mol*kg^{-1}$ soil	Base satur. (%)
							Ca	Mg	K	Na		
1986			6.4	0.080	0.81	6.9	2.58	1.32	0.10	0.47	6.20	72
1992	Alleycropping systems effect(A)	Control	5.5a	0.047a	0.54a	12.72a	1.33a	0.54 a	0.11a	0.17a	4.28 a	53
		Leucaena	5.5a	0.058b	0.69b	24.28a	1.48a	0.49a	0.11a	0.14a	5.11 a	51
		Cajanus	5.3a	0.050a	0.58a	13.35a	1.49a	0.50a	0.09a	0.13a	5.24 a	46
	Fertilization effect (F)	-NPK	5.6a	0.053a	0.61a	2.45a	1.53a	0.61a	0.09a	0.15a	4.78a	50a
		+NPK	5.2b	0.051b	0.59a	31.11b	1.34a	0.41b	0.12 b	0.14b	4.98a	43a
	Cropping systems effect (C)	Solecropping	5.4a	0.051a	0.60a	19.85a	1.43a	0.48a	0.10a	0.15a	4.68a	43a
		Intercropping	5.5a	0.052a	0.61a	13.73a	1.43a	0.54a	0.10a	0.14a	5.06a	46a
	Alleycropping (A) and fertilizer application (B) – NPK	Control	5.7	0.048	0.57	2.03	1.40	0.66	0.09	0.18	4.39	53
		Leucaena	5.7	0.060	0.69	2.69	1.65	0.57	0.08	0.14	4.83	51
		Cajanus	5.5	0.050	0.57	2.64	1.54	0.60	0.08	0.13	5.11	46
		Means	5.6	0.053	0.61	2.45	1.53	0.61	0.09	0.15	4.78	50
	Alleycropping (A) and fertilization effect (F) +NPK	Control	5.3	0.045	0.52	23.42	1.27	0.12	0.16	4.16	4.16	48
		Leucaena	5.3	0.057	0.68	45.86	1.31	0.14	0.13	5.40	5.40	37
		Cajanus	5.2	0.050	0.58	24.06	1.44	0.41	0.09	0.12	5.38	38
		Means	5.2	0.051	0.59	31.11	1.34	0.41	0.12	0.14	4.98	40
	Cropping systems (C) and fertilizer application (B) Solecropping	+NPK	5.2	0.056	0.60	37.19	1.24	0.36	0.11	0.14	4.70	39
		-NPK	5.6	0.050	0.59	2.50	1.63	0.61	0.09	0.15	4.69	53
		Means	5.5	0.052	0.61	19.85	1.43	0.54	0.10	0.14	5.07	43
	Cropping systems (C) and fertilizer application (B) Intercropping	+NPK	5.3	0.049	0.58	25.04	1.44	0.46	0.12	0.14	5.25	41
		-NPK	5.6	0.052	0.63	2.41	1.43	0.61	0.08	0.15	4.70	48
		Means	5.4	0.051	0.60	13.73	1.43	0.48	0.10	0.15	4.69	46
HSD (0.10)*			0. 5	0. 009	0.11	ns	ns	ns	ns	ns	ns	ns
LSD(0.10)**			0. 1	0. 006	ns	18. 84	ns	ns	ns	ns	ns	ns

* : HSD values for alley cropping means for same fertilizer treatment.
** : LSD values for fertilizer means for same cropping system treatment.
a, b and c (A, B and C): means followed by the same letters within the same columns do not differ significantly at p ≤ =: 0. 05.
(p= 0. 10) *: Available P average values strongly influenced by fertilizer application, which may be seen by fertilized and non-fertilized treatment data

Adjusting the rate and time of application is yet another way, such that nutrient uptake by crops could be near maximum and more efficient (BALASUBRAMANIAN and SINGH, 1982). Both methods applied together could give best results. Available P values recorded at the end of the trial period with regards to fertilizer treatments showed that on soils such as Ultisols, high supply of inorganic P ensured that no P limitation would occur.

Interaction between alley cropping and fertilizer application

When comparisons were made with LSD(0.10), fertilized *Leucaena* prunings improved soil N and C content and pH significantly, over *Cajanus* and the control treatments. The same trends but at lower levels were recorded when the alley prunings were non-fertilized. Regards to available P, exchangeable bases, CEC and bases saturation, no significant difference was observed. According to the analyse of variance, no significant interaction between alley cropping and fertilizer implication was observed. Exchangeable Ca and Mg were more reduced when prunings were applied with fertilizer as compared to application of prunings without fertilizers. Exchangeable K showed 75 per cent of improvement when fertilizers were applied with *Leucaena* prunings over *Leucaena* prunings without fertilizers where its level reached only 0.08 cmol*kg^{-1} soil. Available P values amounted to 2.03 mg*kg^{-1} with the control treatment, 2.69 with *Leucaena* prunings and 2.64 with *Cajanus* prunings when fertilizer is applied. The numbers 11.5, 17 and 9 multiplied those values when fertilizer was applied in respective cases.

pH values in all fertilized treatments were similar, but were slightly lower when compared to unfertilised treatments, where they ranged from 5.5 to 5.7. In general, base saturation with fertilized *Leucaena* and *Cajanus* prunings amounted to about 40 and was about 17 per cent lower as compared to fertilized control plots. Without fertilizer application, the same tendency between *Cajanus* shrubs and the control treatment was observed. Base saturation values were higher with unfertilized treatments than fertilized treatments. CEC values with fertilized *Leucaena* and *Cajanus* prunings reached 5.4 cmol*kg^{-1} soil and were about 30 per cent higher than fertilization without pruning application. Without fertilization, the increase varied from 10 to 17 per cent where the control showed 4.39 cmol*kg^{-1} soil. Reduced base saturation in fertilized alley cropped plots is due to lower Ca and Mg contents. YAMOAH et *al.* (1986), working on an Oxic Paleustolf in Ibadan (Nigeria) reported similar tendencies with prunings from *Cassia siamea* and N fertilizer. AÏHOU et *al.* (1999) and AÏHOU (2003) found similar results in their alley cropping experiments in south of Bénin. They discovered that supplementing alley cropping with mineral fertilizers mainly N and P could regenerate and sustain soil fertility properties. Strongly exchangeable K contents improvement when *Leucaena* prunings were applied with fertilizer as compared to *Leucaena* prunings without fertilizer indicates that application of K mineral fertilizer together with *Leucaena* prunings may help to boost K level in Ultisols compared to what would occur when *Leucaena* prunings were applied without fertilizer. This suggests the importance of K mineral application in such soils. *Cajanus* prunings with fertilizer application did not improve exchangeable K levels over fertilized control without alleys. This means that crop residues returned on fertilized control plots after harvesting maintained K- levels at such a level that additional *Cajanus* pruning from hedgerows had no effect. It seems also that the K contribution by the amount of annual *Cajanus* prunings applied in this study was not able to compensate the K removal by harvested crops and losses through leaching. The improvement of the available P, when fertilizer was applied with *Leucaena* prunings over fertilization with the control and with the *Cajanus* pruning treatments indicates that amount of biomass and maybe the quality of that biomass applied with fertilizers plays an important role in P recycling.

Effects of cropping systems and interaction between fertilizer and cropping systems

No significant differences in soil properties between rotation and intercropping were recorded. However values of all elements showed a tendency of improvement in intercropping maize and cassava systems over biannual maize and cassava rotation systems, except Ca, K and Na. pH values were not significantly different in any of the cropping systems. The similar values of soils chemical properties in respect of both solecropping (rotation between maize and cassava) and intercropping (maize and cassava) systems indicate that it is immaterial if maize and cassava are either intercropped or rotated each year. LAL, (1989 a) reported that continuous cultivation with maize during the main season and cowpea during the minor cropping season resulted in progressive decline of soil organic matter, pH and most soil nutrients with time. Results show that continuous cultivation of maize and cassava in rotation or intercropping within 6 years decreased organic matter by approximately 25 per cent as compared to precultivation levels. This reduction is similar to that found by AWETO et *al.* (1992) for continuous cultivation of cassava intercropped with maize on a ferruginous tropical soil and on an Alfisol on farmlands near Ibadan in southeastern Nigeria. The results suggested that on this site, continuous maize-cassava intercropping using balances rates of mineral fertilizers can sustain soil fertility (AKONDÉ et *al.*, 1997; BERNARD et *al.*, 2000).

According to the analysis of variance, no significant interactions were observed between fertilization and cropping systems with respect to soil nutrient status apart from Ca. This may be due to higher organic C and CEC values within *Leucaena* alley when maize was intercropped with cassava as compared to control without hedgerows and to rotation of sole crop maize and cassava. It is also possible that the continual yearly recycling of nutrients from cassava fallen leaves (especially when it was fertilized) could more improve the CEC than the two-yearly contribution through maize and cassava in rotation. pH values were the same (5.6) when both cropping systems remained unfertilised. When fertilized, intercropped plots gave the highest CEC and lowest organic matter content.

Conclusion

Intensive maize-cassava cropping on a year to year basis on a ‘’terre de barre’’ Ultisol leads to progressive decrease of soil fertility. The decrease in organic matter content observed in all treatments was accompanied by a substantial decline in the contents of the exchangeable bases (Ca, Mg and K), resulting in substantial acidification of the soil. The observed soil degradation could not be arrested by adding mulch from hedgerows to the system. However, organic C, total N, exchangeable Ca, available P and the sum of bases decreased to a smaller extent with *Leucaena leucocephala* based alley cropping than without hedgerows. Exchangeable Ca and CEC in *Cajanus cajan* and *Leucaena leucocephala* based alley cropping systems were higher as compared to control without hedgerow treatments.

Lower rates of soil fertility decline in alley cropping may have advantages compared to continuous non-alley cultivation on Ultisols in Southern Benin.

No difference between rotation or intercropping of maize and cassava were noticed indicating that both cropping systems have the same impact on soil chemical properties. The combination of prunings from *Leucaena leucocephala* with fertilizer application can improve nutrient recycling, especially P and nutrient efficiency regarding those cropping systems.

Under continuous cropping of maize and cassava, fertilization did not lead to an improvement of soil nutrient status except for P. Rather, soil acidification was enhanced.

Acknowledgements

The author is gratefull to the Deutscher Akademischer Austauschdienst for providing scholarship during the whole stage of the work, and Deutsche Forschungsgemeinschaft for financing this study through the ''Special Program 308'' of University of Hohenheim.

Special thanks must also be addressed to Mrs Davakan Inès and Seni Rachidatou for typing this manuscript.

References

Agbenin J. O. & Goladi J.T. (1998): Long term soil fertility trend in the Northern Guinean zone of Nigeria as influenced by farmyard manure and inorganic fertilizers pp. 21-29 in: G. Renard, A. Neef, K. Becker & M. von Oppen (eds.). (1997): Soil fertility management in West African land use systems Proceedings of the regional workshop University of Hohenheim held at ICRISAT Niamey Niger 4-8 March 1997.

Aïhou K., Sanginga N., Vanlauwe B., Lyasse O., Diels J. & Merckx R. (1999): Alley cropping in the moist savanna of West Africa: 1. Restoration and maintenance of soil fertility on terre de barre soils in Benin Republic . Agroforestry Systems 42: 212-227.

Aïhou K. (2003): Interaction between organic input by Cajanus cajan (L.) Millsp and inorganic fertilization to maize in the derived savanna of the Benin Republic. PhD dissertation Gent University Belgium 217 pp.

AkondéT.P., Leihner D.E., Kühne F. & Steinmüller N. (1997): Alley cropping on an Ultisol in subhumid Benin; III. Nutrient budget of maize, cassava and trees. Agroforestry Systems 37: 213-226.

Aweto A.O., Obe O. & Ayanniyi O. (1992): Effects of tree legumes in hedgerows on soil fertility changes and crop performance in the semi-arid highlands of Ruanda. Biol. Agric. And Hortic. 8: 17-32.

Balasubramanian V. & Singh L. (1982): Efficiency of nitrogen fertilizer use under rainfed maize and irrigated wheat at Kadawa, northern Nigeria. Fertilizer research. 3. fertilizer research. 3 : 315-324.

Bernard M., Lose S.J. & Agbo B.P. (2000): Soil fertility management and plant production in Benin: the production potential of different agroforestry systems compared with traditionally managed and fertilised systems pp 297- 319 in F. Graaf, P. Lawrence & W. von Oppen (Eds.): Adapted Farming in West Africa, Potentials and Perspectives.

Boko, A. & Vinh T. (1979): Recueil des méthodes d'analyse des sols. Projet d'Agropédologie. Agonkanmey. Abomey-Calavi, Bénin.

Diatta S. & Siband P. (1998): Evolution of soils under continuous cropping conditions : the case of red ferrallitic soils in Southern Senegal. pp. 221-229 in: G. Renard, A. Neef, K. Becker & M. von Oppen (eds.): Soil fertility management in West African land use systems Proceedings of the regional workshop University of Hohenheim held at ICRISAT Niamey Niger 4 -8 March 1997.

Finck A. (1979): Dünger und Düngung. Veinhem, New York. Verlag Chemie.

Floquet A. (1991a): Farmer's assessment of techniques. ILEIA Newsletter, Special Issue 1 and 2 : 15-18.

Floquet A. (1991b) : Maîtrise de la fertilité du sol par les petits cultivateurs de la province Atlantique, Bénin . In Pratiques d'agriculture écologique pour les petites exploitations tropicales J. Kotschi (ed.) CTA-GTZ. Tropical Agroecology 5 : 33-60.

Gichuru M.P. & Kang B.T. (1989): *Calliandra calothyrsus* in alley cropping system with sequentially cropped maize and cowpea in southwestern Nigeria. Agroforestry Systems 9 : 191-203.

Hulugalle N. R. & Kang B.T. (1990): Effects of hedgerow species in alley cropping systems on surface soil properties of an Oxic Paleustalf in South-Western Nigeria J. of Agric. Sc. Camb. 114: 301-307.

Jansen B.H. (1993): Integrated nutrient management: the use of organic and mineral fertilizers pp. 89 –106 in H. van Reutler and W.H. Prins (eds): The role of plant nutrients for sustainable food crop production in Subsaharian Africa.

Jones M.J. (1976): Effects of three N fertilizers and lime on PH and exchangeable cation content at different depth in cropped soil at two sites in the Nigeria Savanna. Tropical Agriculture. 53 : 243-254.

Jones M.J. & Stockinger K.R. (1976): Effects of fertilizer on exchangeable cations ratios and crop nutrition in northern Nigeria. Expl. Agriculture 12 : 49-53.

Juo A.S.R. (1979): Selected methods for soil and plant analysis. IITA manual series N° 1. Ibadan, Nigeria.

Kang B.T. (1986): Cropping systems and soil fertility management in the humid and subhumid tropics with special reference to West Africa pp. 3-28 in Mokwunye, A.U., Vlek, P.L. G. (eds.): Management of Nitrogen and Phosphorus Fertilizers in Subsaharan Africa. Proceedings of a Symposium held at Lomé, Togo, 25-28 March 1985. Dorderecht, NL Martinus Nijhoff,

Kang B.T. & Wilson G. (1987): The development of alley cropping as a promising agroforestry technology pp 227-243 in Agroforestry : a decade of development (Steppler H.A. and Nair P.K.R. (eds) ICRAF Nairobi .

Kang B.T., Grimme H. & Lawson T.L. (1985): Alley cropping sequentially cropped maize and cowpea with Leucaena on a sandy soil in southern Nigeria. Plant and Soil. Plant and Soil 85 : 267-277.

Kang B.T., Reynolds L. & Atta-krah A.N. (1990): Alley farming. Advances in Agronomy 43 : 315-359.

Lal R. (1989a): Agroforestry systems and soil surface management of tropical alfisol. 1. Soil moisture and crop yields. Agroforestry systems 8(1) : 7-30.

Lal R. (1989b): agroforestry systems and soil surface management of tropical alfisol. 2 : changes in soil chemical properties. Agroforestry Systems 8(1) : 113-132.

Louette D. (1988) : Synthèse des travaux de recherché sur la fertilité des terres de barre au Bénin et Togo. DSA-CIRAD Montpellier .

Matthews R.B., Holden S.T., Volk J. & Lungu S. (1992): The potential of alley cropping in improvement of cultivation systems in the high rainfall areas of Zambia 1 : Chimene and Fundikila. Agroforestry Systems 17 : 219-240.

Obi O. (1989): Long term effects of continuous cultivation of a tropical Ultisol in southern Nigeria. Exp. Agriculture. 25 : 207-215.

Okigbo B.N. (1974): Fitting research to farming systems. Proceedings of the second international seminar on charge in agriculture. Reading , England.

Raunet M. (1973) : Contribution à l'étude pédoagronomique des terres de barre du Dahomey et du Togo. Agronomie Tropicale 28 : 1049-1069.

Van Reutler H. & Prins W.H. (1993): Plant nutrients and food production pp 13-24i in H. van Reutler and W.H. Prins (eds): The role of plant nutrients for sustainable food crop production in Subsaharian Africa.

Rosecrance R. C., Brewbaker J.C. & Foynes J.H. (1992): Alley cropping of maize with nine leguminous trees. Agroforestry Systems 17: 159-168.

Yamoah C.F., Agboola A.A., Wilson C.F. & Mulongoy K. (1986): Soil properties as affected by the use of leguminous shrubs for alley cropping with maize. Agriculture, Ecosystem and Environmen 18: 167-177.